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Classifying sea ice in high-resolution SAR imagery using deep learning

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Sea ice plays a vital role in Earth's human-climate system. It regulates the Earth's overall energy balance by seasonally increasing surface albedo and reflecting solar radiation; it governs thermodynamic exchanges between the ocean and atmosphere and thereby impacts mid-latitude weather patterns; it buttresses key continental ice shelves in Greenland and Antarctica; it provides an ecosystem in which land, marine, and airborne species thrive; it enables the livelihoods of indigenous populations across the Arctic; it poses a major obstacle to global shipping logistics; and it serves as a key indicator of climate change given the sensitivity of the polar regions to anthropogenically-induced warming. Regular and automated monitoring of sea ice concentration and type may therefore prove valuable to a broad and diverse set of parties. Conventional approaches in sea ice monitoring involve the use of remotely sensed microwave radiometer data with low resolution of 6-25 km and high instrumental sensitivities to environmental factors such as atmospheric water vapour, near-surface brightness temperature, and wind-induced surface roughening. Dual-polarity synthetic aperture radar (SAR) imagery offers a higher resolution alternative, which can also distinguish between sea ice and open water year-round independent of weather conditions. However, manual interpretation of such imagery is time-consuming. In this work, we develop a deep learning system to automatically generate high-resolution maps of sea ice concentration and type using 40m-resolution SAR imagery obtained from the Sentinel-1 mission between 2017 and 2021. Focusing on the East Weddell Sea, a region where compacted sea ice is renowned for inhibiting ship navigation and an active area of iceberg calving, we train the system against reference sea ice charts produced through manual interpretation by experts. We identify strengths and weaknesses of the system and discuss implications for future research at the intersection of machine learning and polar science.